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Performance Characteristics of Woodstoves under Field Conditions

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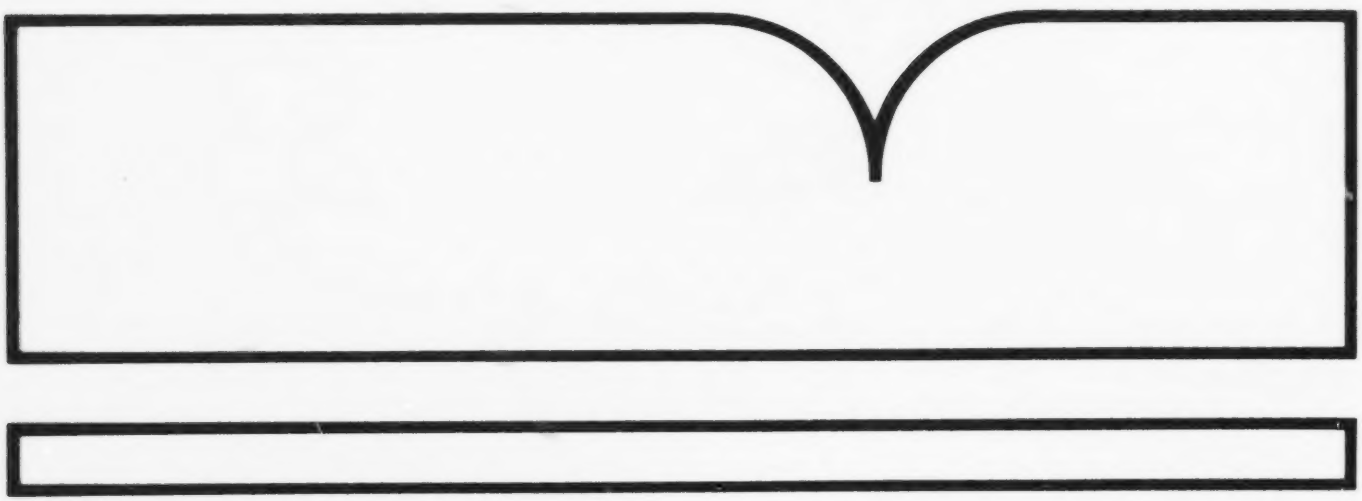

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PERFORMANCE CHARACTERISTICS OF WOODSTOVES UNDER FIELD CONDITIONS

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16. ABSTRACT The paper discusses data and preliminary findings from the first year of a 2-year detailed evaluation of woodstove performance characteristics under field conditions that was conducted on 32 volunteer houses in New York State and Vermont. Woodstoves were monitored for particulate emissions, wood fuel use, and creosote accumulation in the chimney. Comparisons were made between stove technologies represented in the study houses: catalytic, high-efficiency noncatalytic, and conventional stoves. Add-on/retrofit catalytic devices added to conventional stoves were also evaluated. Field results showed that catalytic stoves achieved emission reductions of about 25%, compared to conventional stoves. Prior laboratory tests on the same catalytic stove models indicated reductions of 5 to 10 times were possible. High-efficiency noncatalytic technology, based on very limited data, showed the lowest average emission rates. Add-on/retrofit devices showed no emission reduction.

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Stoves	Creosote	Stationary Sources	13A	11G
Wood	Catalysis	Particulate	11L	07D
Fuels			21D	
Combustion			21B	
Emission			14G	

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ABSTRACT

A detailed evaluation of woodstove performance characteristics under field conditions was conducted on 32 volunteer homes in New York State and Vermont. Woodstoves were monitored for particulate emissions, wood fuel use, and creosote accumulation in the chimney. Comparisons were made between stove technologies represented in the study homes: catalytic, high efficiency noncatalytic, and conventional stoves. Add-on/retrofit catalytic devices added to existing conventional stoves were also evaluated. This paper discusses data and preliminary findings from the first year of the 2-year study. Field results showed that catalytic stoves achieved emission reductions of about 25% compared to conventional stoves. Prior laboratory tests on the same catalytic stove models indicated reductions of 5 to 10 times were possible. High efficiency noncatalytic technology, based on very limited data, showed the lowest average emission rates. Add-on/retrofit devices showed no emission reduction.

PERFORMANCE CHARACTERISTICS OF WOODSTOVES UNDER FIELD CONDITIONS

I. Introduction

Based on the need for credible information on the field performance of catalytic woodstove appliances, the Coalition of Northeast Governors (CONEG) and the New York State Energy Research and Development Authority (NYSERDA) planned a field performance study to examine emissions, efficiency, and safety of high performance stoves versus conventional "airtight" stoves. The Environmental Protection Agency's (EPA's) interest in the durability of catalysts over time prompted their commitment to co-fund the 2-year study. EPA's decision to develop a New Source Performance Standard (NSPS) for woodstoves coincided with CONEG and NYSERDA's decision to conduct the study.

The primary objectives of the study were:

(1) To compare the fuel usage of catalytic and high efficiency noncatalytic stoves and add-on/retrofit catalytic devices with that of conventional airtight stoves in Vermont and New York State homes under actual operating conditions over a period of two heating seasons;

(2) To measure the creosote buildup in the chimney systems of the study homes;

(3) To measure the particulate emission rates of catalytic, high-efficiency, and conventional stoves and add-on/retrofit catalysts over the duration of two heating seasons, from Fall 1985 to Spring 1987; and

(4) to measure emission rates of polycyclic aromatic hydrocarbons (PAH) in a selected subsample of the study stoves.

II. Research Tasks and Methodology

The Vermont Agency for Environmental Protection and the New York State Department of Environmental Protection utilized direct mail and media outreach to recruit volunteers for the study. Each applicant mailed in a questionnaire providing demographic, structural, and heating appliance information. Several criteria--previous woodstove operation experience, safe chimneys, ease of instrumentation, participant's eagerness, geographical proximity, and building structure representativeness--were used to narrow the list. Contractor field staff visited each applicant household before making final selections. From 140 volunteer households, 66 study households (half from Washington County, Vermont, and half from the Warrensburg, New York, area) were selected.

Each participant was placed in one of three categories.

Group One (32 stoves) homes received catalytic, high efficiency non-catalytic, or conventional stoves. Instrumentation measured fuel usage, particulate emission rates, and other stove and household parameters. Group Two (24 stoves) homes used both catalytic and conventional stoves in alternating years. Group Three (6 stoves) homes had catalytic stoves which had experienced at least 1 year of usage before the 1985-1986 heating season. Four backup homes also were available in the event of dropouts or methodological problems. The remainder of this paper addresses preliminary results from the Group One homes for the 1985-86 heating season.

The chimneys of all the participant homes were cleaned at the beginning of the study and at least twice during the heating season. The creosote collected from the cleanings was weighed. Wood piles of every participant were measured and moisture content determined at the beginning, middle, and end of each heating season. Each participating home also received an energy audit. Each participant agreed to keep a daily log for recording unusual events which may have affected fuel usage (e.g., visiting guests, chimney fires). All stoves were furnished and installed by the participating manufacturers.

The Group One homes were equipped with emission samplers, wood scales, and electronic data loggers. The scale/data logger assembly compiled loaded fuel weights and temperatures in various locations. Flue gas oxygen concentrations were also recorded. Of the 32 stoves in Group One, 12 were catalytic stoves, 12 were catalytic add-on retrofit units, 4 were high-efficiency stoves, and 4 were conventional airtight stoves.

III. Data LOG'r and Emissions Sampler Description

Two pieces of specialized equipment were used for this project. One was a computerized data logger/controller, used for recording temperature, wood weight, coal bed status, and flue gas oxygen concentration data. This unit, dubbed the Data LOG'r, also controlled the sampling intervals of the emission sampling system described below. An electronic scale, mounted beneath a wood basket, weighed the amount of wood used in each woodstove. These data, as well as the condition of the coal bed at the time of fuel loading, were recorded in a solid state memory device. Four weeks of continuous data can be recorded at 5-minute intervals without downloading.

The emission sampler, or Automated Woodstove Emission Sampler (AWES), was controlled by the Data LOG'r. At preprogrammed times the AWES pulled flue gas through a heated filter and an XAD-2 sorbent resin cartridge to obtain a particulate sample. The AWES was designed to operate unattended for a week, resulting in an integrated sample for that period. The sampling rate was controlled by a critical orifice, which maintained constant flow. A sensor measured flue oxygen concentrations, which were recorded by the Data LOG'r.

IV. Testing Methodology

The total particulate catch and gas volume sampling were used to calculate particulate concentrations in the flue. Wood use data and flue oxygen concentrations were used to calculate flue gas flow rates. Particulate emissions per heat output, emission rates, and emission factors were also calculated.

AWES units extracted samples from various locations in the stove/chimney system. In all homes, one unit extracted a sample from the chimney at the flue collar. Most homes included a second AWES unit placed either at the top of the chimney or before the catalyst (catalytic stoves and add-on/retrofit installations only). Flue collar measurements allowed comparisons from home to home. Before-catalyst measurements provided a means of determining catalyst destruction efficiency. Chimney top samples indicated the actual emissions to the atmosphere in comparison with the flue collar data. The AWES sampler has been tentatively demonstrated to have comparable accuracy and precision with EPA Method 5 for use on residential wood combustion sources. Additional comparative testing in conjunction with another project is underway.

Polycyclic organic material (POM) analyses are being conducted on selected total sample catches. GC/MS analysis for eight POMs are being conducted. These POMs will be reported in the same units used for particulate material.

V. Preliminary Study Results (1985-86 Data)

Wood use, creosote, and emission data have been collected in the 32 Group One homes for the 1985-86 heating season. Final data processing and analysis is underway on data from the second heating season. A final draft report, including data from the second heating season, will be submitted to the project sponsors in July 1987.

Preliminary findings include:

(1) Creosote accumulation (normalized by heating degree days) is highly variable and appears to be a function of stove operation as well as stove technology. The lowest average creosote accumulations were in the catalytic stove group, which had about half the creosote per heating degree day as the conventional stove group (Figure 1).

(2) Wood use averaged about 25 percent less in the catalytic stove group as compared to the conventional stove group (Figure 1). Wood use was also quite low in the low-emission noncatalytic group, averaging about the same as the catalytic group. However, very limited data were available for this group.

(3) Particulate emissions from the catalytic stove group averaged about 25 percent less than the conventional stove group (Figure 1). These emissions are significantly higher than expected, based on laboratory

testing. Possible factors include catalyst deterioration and lack of operator diligence.

Although only a small data population was available from the first heating season, low-emission noncatalytic stove group results are provocative. Particulate emissions from low emission stoves averaged about half those from conventional stoves. Additional low emission stoves were added to the study for the second heating season to obtain a larger set of data for this technology.

Add-on catalyst devices showed particulate emissions equivalent to those for conventional stoves. Laboratory testing on these devices has indicated that attaining catalyst lightoff may be difficult due to lower flue gas temperatures at a remote flue collar location. Conventional stoves had average particulate emissions of about 32 g/hr, similar to those documented in laboratory testing.

(4) Catalyst durability is being monitored by measuring particulate emissions over the two heating seasons. However, to eliminate the large number of variables encountered in the field, three combustors were returned for testing under laboratory conditions between the first and second heating season. Baseline data already existed for these combustors. All combustors were visually inspected before retesting. Baseline field and retesting data were compared.

Results from laboratory retesting indicated that one combustor (A) operated similarly in the laboratory and field and had lost little of its effectiveness (Figure 2). A second combustor (B) showed low emissions in laboratory retesting but high field emissions, indicating either a stove or operator problem in the field (Figure 3). A third combustor (C) showed a high emission rate in laboratory retesting and similarly high results from field testing, indicating a loss of combustor effectiveness (Figure 4).

The data base for this study will be more than doubled at the completion of sampling for the 1986-87 heating season. Additional findings will be reported in a future paper.

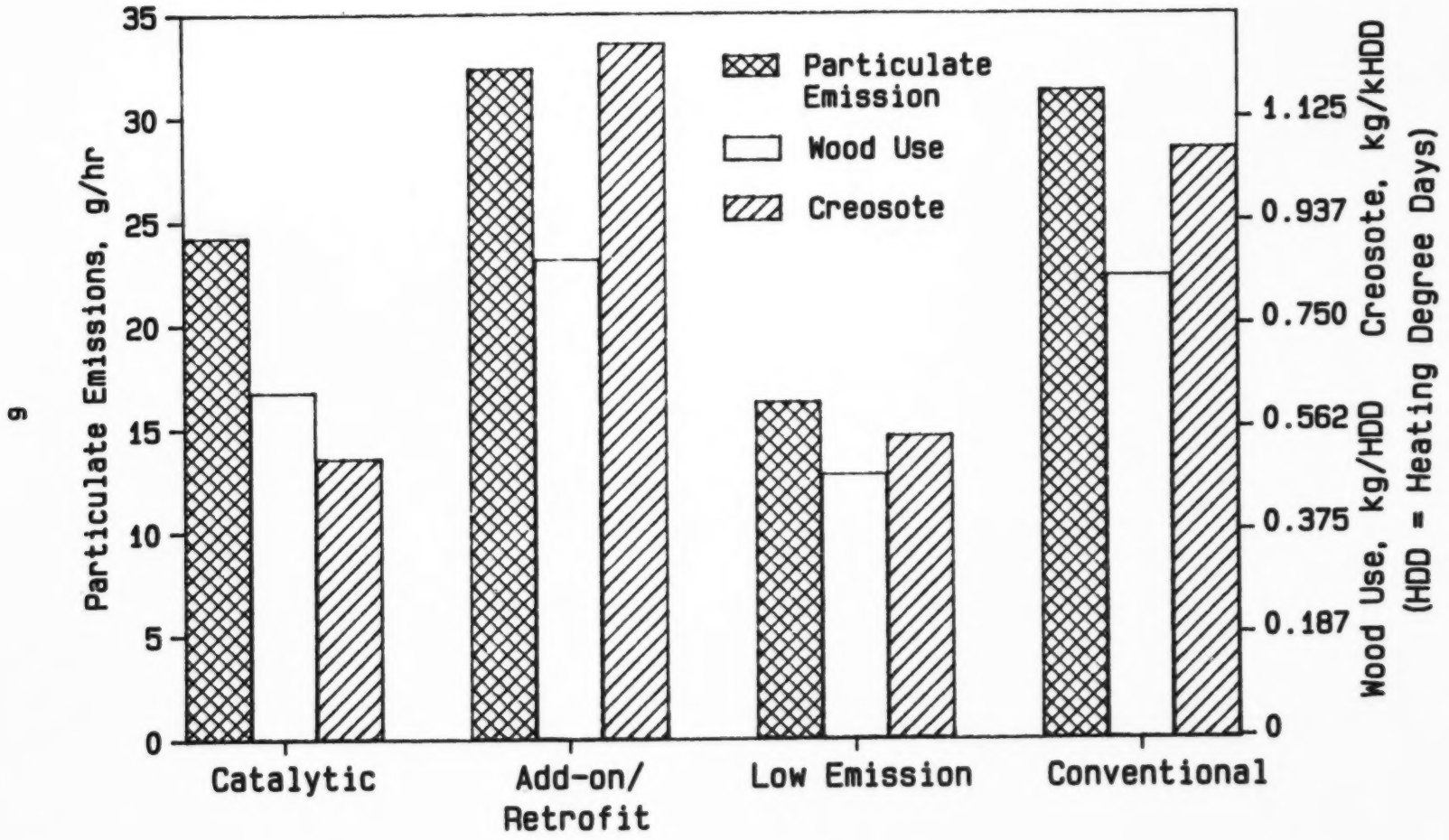

Figure 1. Comparison of performance by stove technology group.

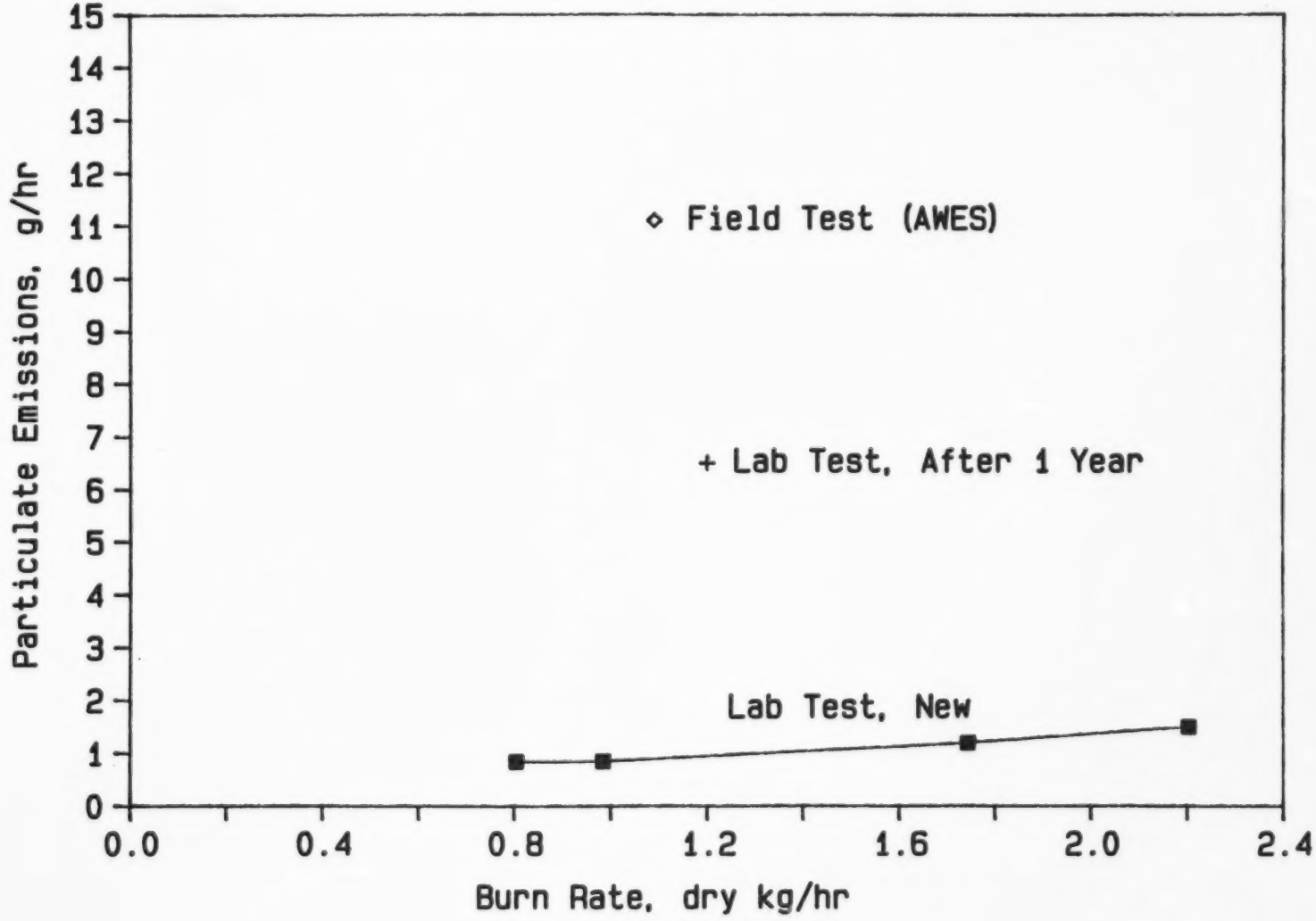

Figure 2. Catalyst combustor A effectiveness.

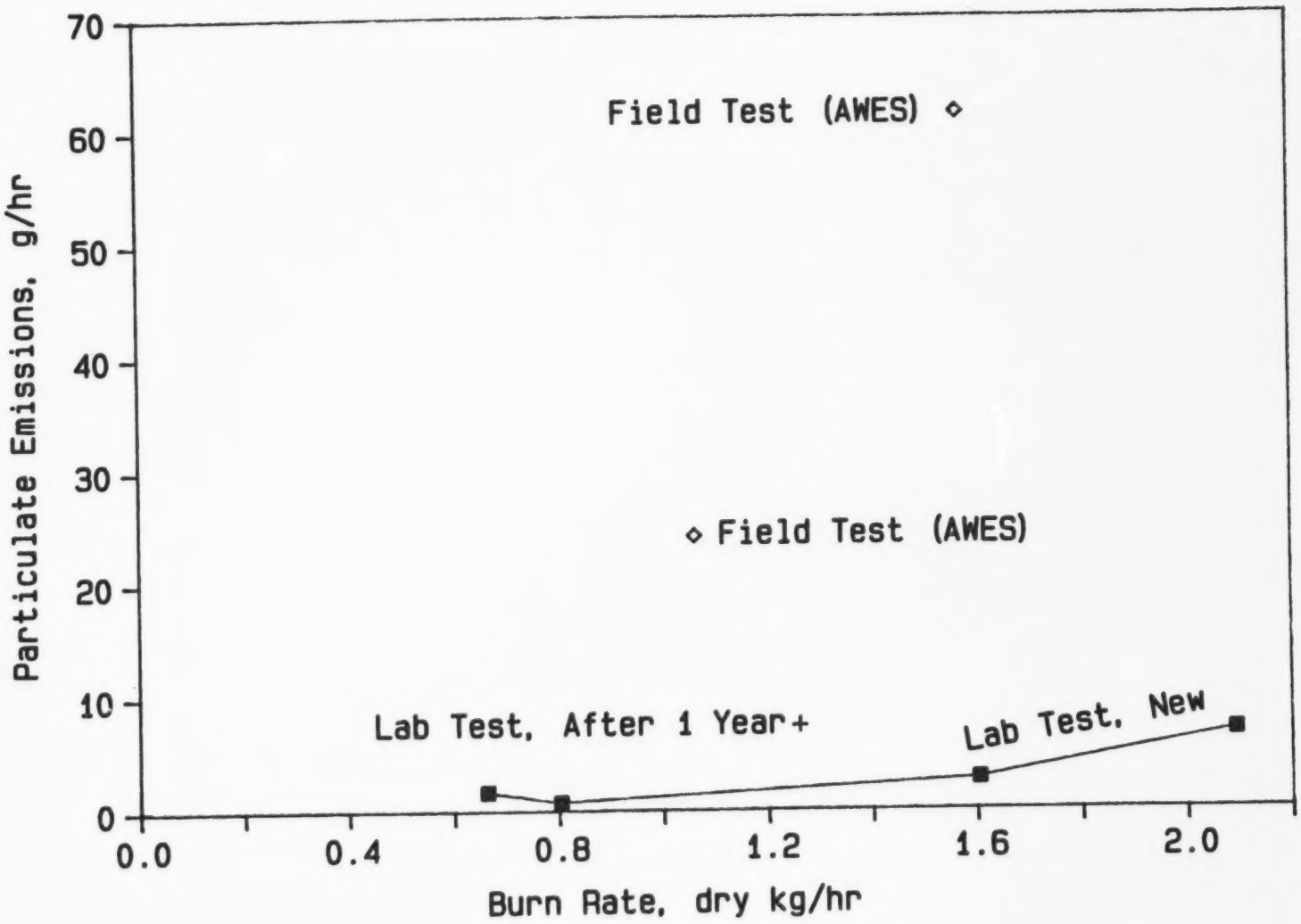

Figure 3. Catalyst combustor B effectiveness.

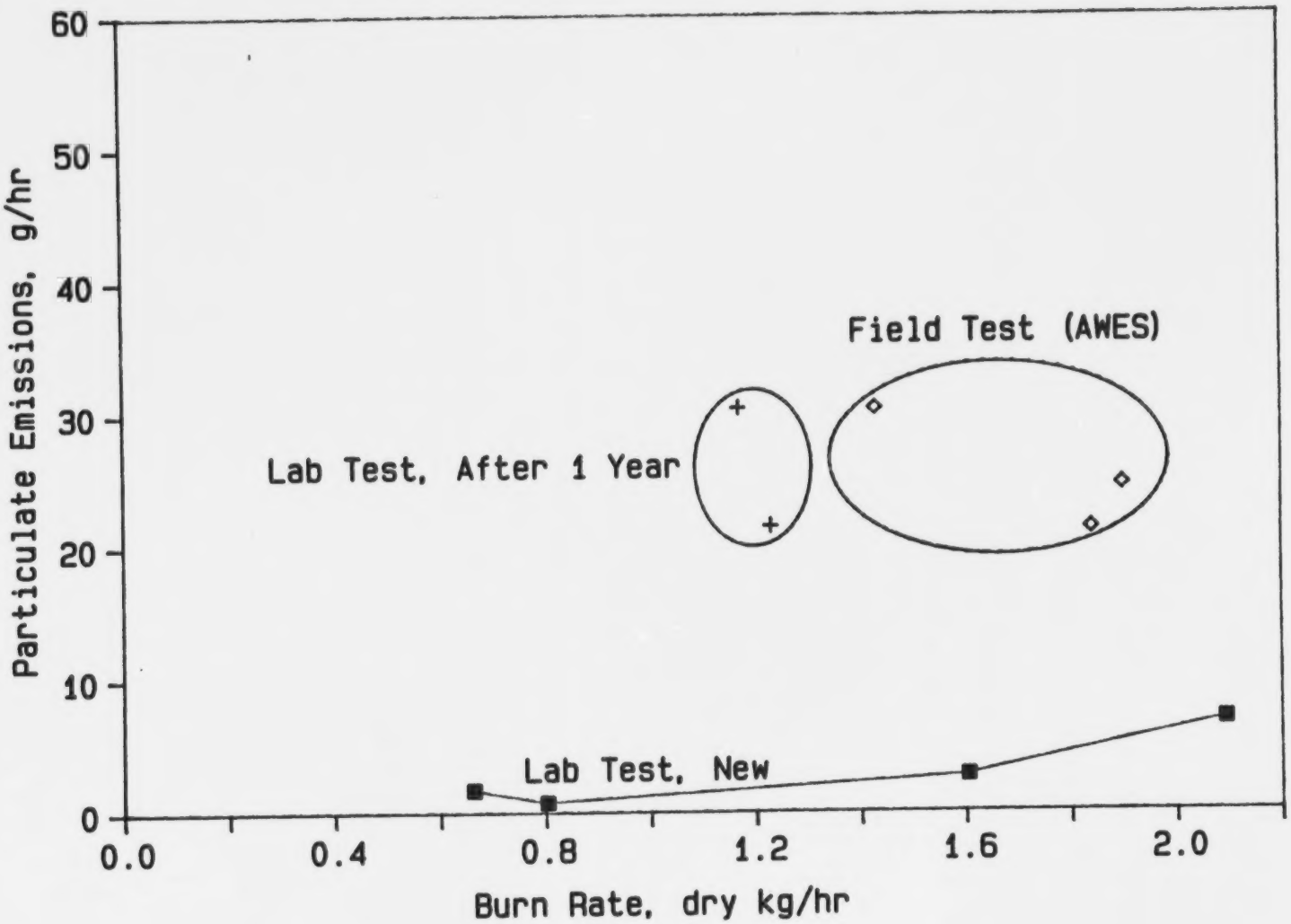

Figure 4. Catalyst combustor C effectiveness.